



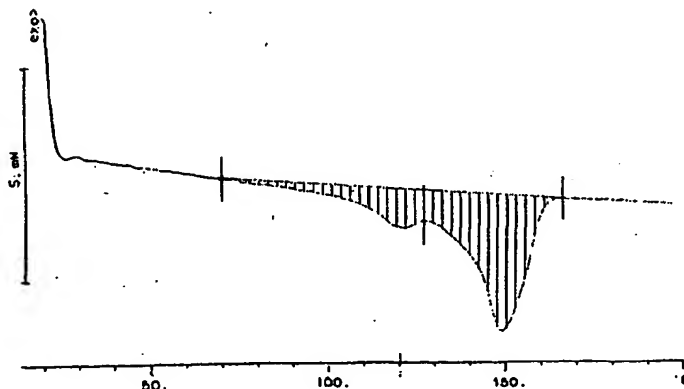
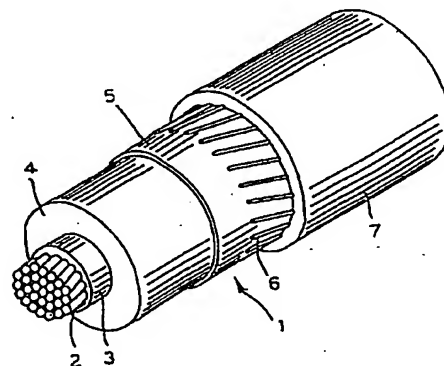
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>7</sup> : <b>H01B 3/44, C08L 23/16</b>		<b>A1</b>	(11) International Publication Number: <b>WO 00/41187</b>
			(43) International Publication Date: 13 July 2000 (13.07.00)
(21) International Application Number: PCT/EP99/10296		(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).	
(22) International Filing Date: 21 December 1999 (21.12.99)			
(30) Priority Data: 98830800.3 30 December 1998 (30.12.98) EP 60/118,804 4 February 1999 (04.02.99) US			
(71) Applicant (for all designated States except US): PIRELLI CAVI E SISTEMI S.P.A. [IT/IT]; Viale Sarca, 222, I-20126 Milano (IT).			
(72) Inventors; and (75) Inventors/Applicants (for US only): CASTELLANI, Luca [IT/IT]; Via Copernico, 19/D, I-20094 Corsico (IT). SCELZA, Cristiana [IT/IT]; Via San Salvatore, 6, I-84044 Angellara di Vallo della Lucania (IT). ALBIZZATI, Enrico [IT/IT]; Via Trieste, 2, I-28040 Lesa (IT).			
(74) Common Representative: PIRELLI CAVI E SISTEMI S.P.A.; Viale Sarca, 222, I-20126 Milano (IT).		Published With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.	

(54) Title: CABLES WITH A RECYCLABLE COATING

## (57) Abstract

Cable, in particular for medium-voltage or high-voltage electrical power transmission or distribution, for telecommunications or for data transmission, comprising a conductor and at least one coating layer based on a non-crosslinked polymer material comprising a heterogeneous copolymer with an ethylene-based elastomeric phase copolymerized with an  $\alpha$ -olefin and a propylene-based thermoplastic phase, in which the said elastomeric phase in the said heterogeneous copolymer is at least 45 % by weight relative to the total weight of the heterogeneous copolymer, and the said heterogeneous copolymer is essentially free of crystallinity deriving from polyethylene sequences.



**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakhstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

# "CABLES WITH A RECYCLABLE COATING"

\*\*\*\*\*

The present invention relates to cables, in particular for medium-voltage or high-voltage electrical power transmission or distribution, for telecommunications or for data transmission, as well as combined power/telecommunications cables, in which at least one coating layer consists of a halogen-free recyclable material which has high-performance mechanical and electrical properties.

There is currently a great need for products which are highly environment-friendly, formed of materials which are not only harmless to the environment both during production and during use, but are also easy to recycle at the end of their life. However, the use of environment-friendly materials is highly conditioned by the requirements for keeping their costs within acceptable limits and at the same time ensuring satisfactory performance levels under the most common conditions of use, or even better performance than those of conventional materials.

In the cables sector, in particular medium-voltage or high-voltage electrical power transmission or distribution cables, the various coatings which surround the conductor usually consist of crosslinked polymer material, in particular of polyethylene or ethylene copolymers suitably crosslinked during the extrusion phase. The reason for this is that these crosslinked materials maintain a high degree of flexibility and satisfactory mechanical properties even under hot conditions in continuous use and/or under conditions of current overload. However, it is well known that crosslinked materials are not recyclable and that, at the end of their life, they can only be disposed of by incineration. In addition, in certain cases the outer protective sheath is formed of polyvinyl chloride (PVC) which is difficult to separate by conventional methods (for example by density differences in water) - from

- 2 -

crosslinked polyolefins containing inorganic fillers (for example ethylene/propylene rubbers containing inorganic fillers), nor can it be incinerated just as it is, by combustion, since this generates highly toxic chlorinated products.

- 5 Patent application WO 96/23311 describes a low-voltage high-current cable in which the insulating coating, the inner sheath and the outer sheath are made of the same non-crosslinked polymer material which is coloured black by the addition of carbon black. Using the same material would not require the separation of the
- 10 abovementioned components in a recycling process. When temperatures below 70°C are used, a polyethylene with a density of between 0.92 and 0.94 g/cm<sup>3</sup> and a Shore D hardness  $\geq 42$  is proposed as polymer material for the insulating coating, the inner sheath and the outer sheath. The use of thermoplastic elastomers
- 15 consisting of two-phase mixtures of polypropylene with an ethylene/propylene co- or terpolymer (EPR or EPDM rubber) is proposed in the case of a maximum working temperature of 90°C. Within the latter class of polymers, mention is specifically made of the commercial products Santoprene® from Monsanto (polypropylene-
- 20 based thermoplastic elastomer) and Novolen® from BASF (heterogeneous propylene copolymers obtained in a reactor and having an ethylene/propylene elastomeric phase content of greater than 25% by weight, for example 43% by weight of ethylene/propylene rubber, such as Novolen® 2912 HX from BASF).
- 25 The Applicant has observed that the technical problem of obtaining a recyclable polymer material for coating electrical cables, in particular medium- or high-voltage cables, which has the desired combination of electrical and mechanical properties can be solved by using a heterogeneous copolymer comprising an ethylene-based
- 30 elastomeric phase copolymerized with an  $\alpha$ -olefin and a propylene-

- 3 -

- based thermoplastic phase, characterized in that the elastomeric phase is at least 45% by weight relative to the total weight of the heterogeneous copolymer and in that this copolymer is essentially free of crystallinity deriving from polyethylene sequences. In point of
- 5 fact, it has been suggested that a large amount of elastomeric phase combined with a substantial absence of crystalline polyethylenic sequences gives, on the one hand, the desired mechanical properties for an electrical cable, and in particular a breaking load value of greater than 12 MPa (measured according to CEI standard 20-34 §
- 10 5.1), and, on the other hand, excellent electrical insulation properties, in particular low dielectric losses, even under hot conditions and in particular at the maximum working temperature of the cable, with values for the tangent of the angle of loss ( $\tan \delta$ ) at 90°C (measured according to ASTM standard D150) of less than  $5 \times 10^{-4}$ .
- 15 In a first aspect thereof, the present invention thus relates to a cable comprising a conductor and at least one coating layer based on a non-crosslinked polymer material comprising a heterogeneous copolymer with an ethylene-based elastomeric phase copolymerized with an  $\alpha$ -olefin and a propylene-based thermoplastic phase,
- 20 characterized in that the said elastomeric phase in the said heterogeneous copolymer is at least 45% by weight relative to the total weight of the heterogeneous copolymer, and in that the said heterogeneous copolymer is essentially free of crystallinity deriving from polyethylene sequences.
- 25 According to another aspect, the invention relates to a cable comprising a conductor and at least one coating layer, in which the said coating layer has electrical insulating properties and is based on a non-crosslinked polymer material comprising a heterogeneous copolymer as defined above.

- 4 -

According to a further aspect, the invention relates to a cable comprising a conductor and at least one coating layer, in which the said coating layer has semiconductive properties and is based on a non-crosslinked polymer material comprising a heterogeneous  
5 copolymer as defined above.

According to a further aspect, the invention relates to a cable comprising a conductor and at least one coating layer, in which the said coating layer functions as an outer protective sheath and is based on a non-crosslinked polymer material comprising a  
10 heterogeneous copolymer as defined above.

According to a further aspect, the invention relates to a cable comprising a conductor and at least one coating layer based on a non-crosslinked polymer material, in which at least 70%, preferably at least 90%, by weight of the said non-crosslinked polymer material  
15 consists of a heterogeneous copolymer as defined above.

For the purposes of the present description and the claims which follow, the expression "heterogeneous copolymer comprising an ethylene-based elastomeric phase copolymerized with an  $\alpha$ -olefin and a propylene-based thermoplastic phase" means a thermoplastic  
20 elastomer obtained by sequential copolymerization of: (a) propylene, optionally containing small amounts of at least one olefinic comonomer chosen from ethylene and  $\alpha$ -olefins other than propylene; and then: (b) a mixture of ethylene with an  $\alpha$ -olefin, in particular propylene, and optionally with small proportions of a diene.  
25 This class of products is also commonly known as "thermoplastic reactor elastomers".

Throughout the present description and the claims which follow, the expression "heterogeneous copolymer essentially free of crystallinity deriving from polyethylenic sequences" means that the  
30 heterogeneous copolymer subjected to differential scanning

- 5 -

calorimetry (DSC) analysis does not show any appreciable melting peaks attributable to a crystalline polyethylenic phase, i.e. to  $(CH_2)_n$  sequences of crystalline type. In quantitative terms, this means that the value of the enthalpy of fusion of peaks present below 130°C and  
5 attributable to polyethylenic sequences is generally less than 3 J/g: preferably, it is substantially zero.

Alternatively, the substantial absence of crystallinity due to polyethylenic sequences can be ascertained by extraction of the elastomeric (amorphous) phase by means of a suitable organic  
10 solvent (for example xylene at 135°C at reflux for 20 min.) and analysis of the residue formed by the crystalline phase, for example by means of X-ray diffractometry. The substantial absence of reflection typical of crystalline polyethylene at the angle  $2\theta = 21.5^\circ$  (with radiation of the copper) indicates that the heterogeneous  
15 copolymer is essentially free of crystalline polyethylenic sequences.

The amount of elastomeric phase present in the heterogeneous copolymer can be determined by known techniques, for example by extracting the elastomeric (amorphous) phase with a suitable organic solvent (in particular xylene at 135°C at reflux for 20 min): the amount  
20 of elastomeric phase is calculated as the difference between the initial weight of the sample and the weight of the dried residue.

In accordance with the present invention, the use of a heterogeneous copolymer as defined above gives a flexible recyclable coating with excellent mechanical properties, in terms of  
25 both breaking load and elongation at break. In particular, it is possible to obtain mechanical performance levels under hot conditions, i.e. at 90°C for continuous use and at 130°C in the case of a current overload, which are comparable with the typical performance levels of the polyethylene-based crosslinked coatings currently marketed,  
30 thereby making the abovementioned heterogeneous copolymer

- 6 -

suitable for coating not only low-voltage electrical cables, but preferably medium-voltage or high-voltage cables.

For the purposes of the present invention, the term "low voltage" generally means a voltage of less than 5 kV, the term "medium voltage" means a voltage of between 5 and 35 kV, while "high voltages" are considered to be voltages above 35 kV.

With particular reference to medium-voltage and high-voltage cables, the heterogeneous copolymers as defined above can be used advantageously to prepare an insulating layer. The reason for this is that, as mentioned above, these copolymers have high-performance mechanical properties both at room temperature and under hot conditions, and moreover have adequate electrical properties, with low tan delta and permittivity values and thus low dielectric losses in alternating current, which, as is known, are proportional to the product between tan delta and permittivity.

In addition, the same heterogeneous copolymers defined above can be used advantageously to prepare at least one inner or outer semiconductive layer. The reason for this is that the addition to these copolymers of fillers capable of imparting semiconductive properties, for example carbon black, does not substantially challenge the mechanical properties, which are maintained well below the values considered as suitable for semiconductive layers. The possibility of using the same type of polymer material both for the insulating layer and for the semiconductive layers is particularly advantageous in the production of medium-voltage or high-voltage cables, since it ensures optimal adhesion between adjacent layers and thus better electrical behaviour, especially at the interface between the insulating layer and the inner semiconductive layer where the electrical field is stronger and thus the risk of partial discharges are greater.



- 7 -

Heterogeneous copolymers whose structural properties and relevant physicochemical properties vary within a wide range are commercially available, for example under the tradename Hifax® from Montell. However, by means of the teaching provided in the present description, a person skilled in the art will readily be able to select the heterogeneous copolymers which are most suitable for carrying out the present invention.

Generally, the said heterogeneous copolymers are prepared by sequential copolymerization of: (a) propylene, optionally containing at least one olefinic comonomer chosen from ethylene and  $\alpha$ -olefins other than propylene; and then of: (b) a mixture of ethylene with an  $\alpha$ -olefin, in particular propylene, and optionally a diene. The copolymerization is usually carried out in the presence of Ziegler-Natta catalysts based on halogenated titanium compounds supported on magnesium chloride. Details regarding the preparation of these copolymers are given, for example, in EP-A-0,400,333, EP-A-0,373,660 and US-A-5,286,564.

The term " $\alpha$ -olefin" refers to an olefin of formula  $\text{CH}_2=\text{CH-R}$ , where R is a linear or branched alkyl containing from 1 to 10 carbon atoms. The said  $\alpha$ -olefin can be chosen, for example, from: propylene, 1-butene, 1-pentene, 1-hexene, 1-octene, 1-dodecene and the like.

The thermoplastic phase of the heterogeneous copolymer, mainly produced during the abovementioned phase (a) of the process, consists of a propylene homopolymer or a crystalline copolymer of propylene with an olefinic comonomer chosen from ethylene and  $\alpha$ -olefins other than propylene. Preferably, the olefinic comonomer is ethylene. The amount of olefinic comonomer is preferably less than 10 mol% relative to the total number of moles of the thermoplastic phase.

- 8 -

As mentioned above, the elastomeric phase of the heterogeneous copolymer, mainly produced during the abovementioned phase (b) of the process, is at least 45% by weight, preferably at least 55% by weight and even more preferably at least 60% by weight, relative to the total weight of the heterogeneous copolymer, and consists of an elastomeric copolymer of ethylene with an  $\alpha$ -olefin and optionally with a diene. The said  $\alpha$ -olefin is preferably propylene. The diene optionally present as comonomer generally contains from 4 to 20 carbon atoms and is preferably chosen from: linear (non-)conjugated diolefins, for example 1,3-butadiene, 1,4-hexadiene, 1,6-octadiene and the like; monocyclic or polycyclic dienes, for example 1,4-cyclohexadiene, 5-ethylidene-2-norbornene, 5-methylene-2-norbornene and the like. The composition of the elastomeric phase is generally as follows: from 15 to 85 mol% of ethylene, from 15 to 85 mol% of  $\alpha$ -olefin, from 0 to 5 mol% of a diene.

In a preferred embodiment, the elastomeric phase consists of an elastomeric copolymer of ethylene and propylene which is rich in propylene units, this copolymer in particular having the following composition: from 15 to 50% by weight, more preferably from 20 to 40% by weight, of ethylene, and from 50 to 85% by weight, more preferably from 60 to 80% by weight, of propylene, relative to the weight of the elastomeric phase.

The amount of propylene units in the elastomeric phase can be determined by extraction of the elastomeric phase as described above (for example with xylene at 135°C at reflux for 20 min), followed by analysis of the dried extract according to known techniques, for example by infrared (IR) spectroscopy.

In one embodiment of the present invention, the said at least one coating layer based on a non-crosslinked polymer material comprises a mixture of a heterogeneous copolymer as defined above with a

- 9 -

thermoplastic polymer which has a melting point of greater than 160°C. This thermoplastic polymer is preferably chosen from crystalline propylene homopolymers and copolymers with a enthalpy of fusion of greater than 75 J/g, preferably greater than 85 J/g. The  
5 presence of this thermoplastic polymer makes it possible to increase the heat-pressure resistance of the cable coating, and is particularly preferred when the thermoplastic phase of the heterogeneous copolymer used has a melting point of less than 150°C. The amount  
10 of thermoplastic polymer to be used mixed with the heterogeneous copolymer according to the present invention is generally between 10 and 50% by weight, preferably between 20 and 40% by weight, relative to the total weight of the said mixture.

Other conventional components such as antioxidants, fillers, processing co-adjuvants, lubricants, pigments, water-free retardant  
15 additives, voltage stabilizer additives and the like can be added to the base polymer material consisting of a heterogeneous copolymer as defined above, optionally mixed with the said thermoplastic polymer. When it is intended to prepare a semiconductive layer, the polymer material is preferably filled with carbon black, in an amount such as to  
20 give this material semiconductive properties (i.e. so as to obtain a resistivity of less than 5 ohm.m at room temperature). This amount is generally between 5 and 80% by weight, preferably between 10 and 50% by weight, relative to the total weight of the compound.

Conventional antioxidants which are suitable for this purpose are,  
25 for example: polymerized trimethyldihydroquinoline, 4,4'-thiobis(3-methyl-6-tert-butyl)phenol; pentaerithrityl tetra[3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate], 2,2'-thiodiethylene bis[3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate] and the like, or mixtures thereof.

Other fillers which can be used in the present invention include, for  
30 example: calcium carbonate, calcined kaolin, talc and the like, or

- 10 -

mixtures thereof. Processing co-adjuvants usually added to the polymer base are, for example, calcium stearate, zinc stearate, stearic acid, paraffin wax, silicone rubbers and the like, or mixtures thereof.

- 5 Further details will be illustrated in the detailed description which follows, with reference to the appended drawings, in which:

Fig. 1 is a perspective view of an electrical cable, which is particularly suitable for medium voltages, according to the present invention;

- 10 Figs. 2 and 3 show the DSC curves of two heterogeneous copolymers according to the present invention (copolymers 1 and 2 respectively);

Figs. 4 and 5 show the DSC curves of two comparative heterogeneous copolymers (copolymers 3 and 4 respectively).

- 15 In Figure 1, the electrical cable 1 comprises a conductor 2; an inner layer 3 with semiconductive properties; an intermediate layer 4 with insulating properties; an outer layer 5 with semiconductive properties; a screen 6; and an outer sheath 7.

- 20 The conductor 2 generally consists of metal wires, preferably made of copper or aluminium, which are braided together according to conventional techniques.

- 25 At least one of the layers 3, 4 and 5, and preferably at least the insulating layer 4, comprises, as non-crosslinked base polymer material, a heterogeneous copolymer as defined above, which is essentially free of crystallinity attributable to polyethylene sequences and in which the elastomeric phase is at least 45% relative to the total weight of the said heterogeneous copolymer.

In a preferred embodiment of the present invention, all of the insulating and semiconductive layers 3, 4 and 5 comprise, as non-

- 11 -

crosslinked base polymer material, a heterogeneous copolymer as defined above.

A screen 6 consisting, for example, of helically wound metal wires or strips is preferably placed around the outer semiconductive layer 5.

- 5 Alternatively, the screen 6 can consist of a continuous tubular component made of metal, preferably aluminium or copper. The screen 6 is then usually coated with a sheath 7 consisting of a thermoplastic material such as polyvinyl chloride (PVC), non-crosslinked polyethylene (PE) or, preferably, a heterogeneous  
10 copolymer as defined above.

Fig. 1 shows only one possible type of cable according to the present invention. Needless to say, appropriate changes known in the art may be made to this embodiment without thereby departing from the scope of the present invention. In particular, telecommunications  
15 cables or data transmission cables, or alternatively combined power/telecommunications cables, can be made by using a heterogeneous copolymer as defined above in at least one of the coatings made of plastic material.

A number of properties of heterogeneous copolymers according to the present invention (copolymers 1 and 2) and of comparative heterogeneous copolymers (copolymers 3 and 4) are given in Table  
20 1.

The melt flow index (MFI) was measured at 230°C and 21.6 N according to ASTM standard D 1238/L.

- 25 The enthalpy of fusion deriving from polypropylene sequences (PP enthalpy) and the enthalpy of fusion deriving from polyethylene sequences (PE enthalpy) was measured using Mettler DSC equipment (second fusion value) with a scan speed of 10°C/min (instrument head: DSC 30 type; microprocessor: PC 11 type;  
30 software: Mettler Graphware TA72AT.1). The DSC curves for the four

- 12 -

heterogeneous copolymers of Table 1 are illustrated in Figures 2-5. It should be noted that the DSC curve for copolymer 2 has a single melting peak relative to the polypropylene phase centred on about 145°C, with a highly pronounced "tail" extending below 130°C, which can be attributed to the presence of a polypropylene phase of low crystallinity presumably due to the presence of short sequences of propylene units interrupted by ethylene units.

The percentage of elastomeric phase was determined by extraction with xylene at 135°C at reflux for 20 min., calculated as the difference between the initial weight of the sample and the weight of the dried residue.

The propylene content in the elastomeric phase was determined by IR spectroscopic analysis of the polymer extracted as described above and dried by evaporation of the solvent. By means of suitable calibration curves, the propylene content is determined as the ratio between the intensity of the bands at 4377 and 4255 cm<sup>-1</sup>.

TABLE 1

Thermoplastic elastomer	MFI (dg/min.)	PP enthalpy (J/g)	PE enthalpy (J/g)	Elastomeric phase (% by weight)	Propylene in the elastomeric phase (% by weight)
Cop. 1	0.8	32.0	0	60	72
Cop. 2	0.6	23.8	0	65	72
Cop. 3(*)	0.9	35.4	7.3	55	41
Cop. 4(*)	7.5	42.8	15.4	48	40

(\*) Comparative

Cop. 1: Hifax® KS080 from Montell;

Cop. 2: Hifax® CA10A from Montell

Cop. 3: Hifax® CA12A from Montell

Cop. 4: Hifax® CA43A from Montell.

The tan delta values at 20°C and 90°C and the permittivity values at 20°C, with a gradient of 1 kV/mm at 50 Hz, were measured according to ASTM standard D150 on the heterogeneous copolymers Cop. 1-3, moulded at 195°C with preheating for 15 min so as to obtain plates 1 mm thick. The results are given in Table 2.

TABLE 2

Product	tan delta at 20°C	tan delta at 90°C	Relative permittivity at 20°C
Cop. 1	$3.0 \times 10^{-4}$	$3.0 \times 10^{-4}$	2.30
Cop. 2	$1.0 \times 10^{-4}$	$2.0 \times 10^{-4}$	2.27
Cop. 3(*)	$3.0 \times 10^{-4}$	$2.1 \times 10^{-3}$	2.36

(\*) comparative

As can be seen, the heterogeneous copolymers which can be used as insulating coating in the cables according to the present invention show tan-delta and relative permittivity values, and consequently dielectric losses in alternating current, which are substantially lower than those of the comparative heterogeneous copolymers.

The heterogeneous copolymers Cop. 1 and Cop. 3 were used to prepare the compositions given in Table 3 (Examples 1 - 4).

These compositions were prepared using a 1.6-litre Banbury mixer with volume-based filling coefficient of about 75%. Plates 1 mm thick were prepared by compression moulding of the compositions thus obtained at 190-195°C and 200 bar after preheating for 10 minutes at the same temperature. Punch samples were obtained from these plates, on which samples were measured the breaking load (B.L.) and the elongation at break (E.B.) according to CEI standard 20-34 §

- 14 -

5.1, using an Instron machine and a pulling speed of the clamps equal to 50 mm/min. The results are given in Table 3.

The compounds of Examples 1 and 3 and those of Examples 2 and 4 (comparative) were used to prepare, respectively, a first medium-voltage cable according to the invention and a second comparative medium-voltage cable. In particular, the compounds of Examples 3 and 4 were used to produce the insulating layer, while the compounds of Examples 1 and 2 were used to produce the inner and outer semiconductive layers.

10 The cables were prepared by extrusion, through a triple-head extruder, onto a 1/0 AWG conductor consisting of a cord of aluminium wires with a cross section of about 54 mm<sup>2</sup>. The extruder, with an inside diameter of 100 mm, had the following temperature profile: from 140 to 210°C in the cylinder, 230°C on the collar and 235°C at the head. The line speed was 2 m/min. The cables thus obtained had a 0.5 mm thick inner semiconductive layer, a 4.6 mm insulating layer and a 0.5 mm outer semiconductive layer.

From the insulating layer were obtained punch samples required to determine the mechanical properties according to CEI standard 20-34 § 5.1, using an Instron machine and a pulling speed equal to 50 mm/min. The results are given in Table 3.

As can clearly be seen from the data reported in Table 3, the insulating and semiconductive coatings on the cable according to the invention have E.B. and B.L. values which are significantly better than the comparative values.



- 15 -

TABLE 3

Examples	1	2(*)	3	4(*)
Cop. 1	100	-	100	-
Cop. 3	-	100	--	100
Corax N550	20	20	-	-
Conductex® 975	25	25	-	-
Irganox® 1010	0.2	0.2	0.1	0.1
Irganox® PS802	0.4	0.4	0.2	0.2
Mechanical properties of the plates				
E.B. (%)	595	222	733	104
B.L. (MPa)	14.4	7.3	23.2	8.0
Mechanical properties of the 1/0 AWG cable				
E.B. (%)	-	-	521	316
B.L. (MPa)	-	-	18.4	9.3

(\*) comparative

Corax N550: carbon black from Degussa (surface area 42 m<sup>2</sup>/g - measured with nitrogen according to ASTM D 3765; iodine number = 43 mg/g according to ASTM D 1510);

Conductex® 975: conductive carbon black from Columbia Chemicals (surface area 250 m<sup>2</sup>/g - measured with nitrogen according to ASTM D 3765; iodine number = 247 mg/g according to ASTM D 1510);

10 Irganox® PS802; distearyl thiopropionate (DSTDP) (antioxidant from Ciba Geigy);

Irganox® 1010; pentaerythritol tetrakis[3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate] (antioxidant from Ciba-Geigy).

## CLAIMS

1. Cable comprising a conductor and at least one coating layer based on a non-crosslinked polymer material comprising a heterogeneous copolymer with an ethylene-based elastomeric phase  
5 copolymerized with an  $\alpha$ -olefin and a propylene-based thermoplastic phase, characterized in that the said elastomeric phase in the said heterogeneous copolymer is at least 45% by weight relative to the total weight of the heterogeneous copolymer, and in that the said heterogeneous copolymer is essentially free of crystallinity deriving  
10 from polyethylene sequences.
2. Cable according to Claim 1, characterized in that at least 70%, preferably at least 90%, by weight of the said non-crosslinked polymer material consists of the said heterogeneous copolymer.
3. Cable according to Claim 1 or 2, characterized in that, in the said  
15 heterogeneous copolymer, the value of the enthalpy of fusion of peaks present below 130°C and attributable to polyethylene sequences is less than 3 J/g.
4. Cable according to Claim 3, characterized in that, in the said heterogeneous copolymer, the value of the enthalpy of fusion of  
20 peaks present below 130°C and attributable to polyethylene sequences is substantially zero.
5. Cable according to any one of Claims 1 to 4, characterized in that the said elastomeric phase consists of an elastomeric copolymer of ethylene and propylene which comprises from 15 to 50% by weight  
25 of ethylene and from 50 to 85% by weight of propylene, relative to the weight of the elastomeric phase.
6. Cable according to Claim 5, characterized in that the said elastomeric phase consists of an elastomeric copolymer of ethylene and propylene which comprises from 20 to 40% by weight of ethylene

- 17 -

and from 60 to 80% by weight of propylene, relative to the weight of the elastomeric phase.

7. Cable comprising a conductor and at least one coating layer based on a non-crosslinked polymer material, characterized in that  
5 the said non-crosslinked polymer material comprises a mixture of a heterogeneous copolymer, as defined in any one of the preceding Claims 1 to 6, with a thermoplastic polymer which has a melting point of greater than 160°C.

8. Cable according to the preceding Claim 7, characterized in that  
10 the said thermoplastic polymer is chosen from crystalline propylene homopolymers and copolymers with a enthalpy of fusion of greater than 75 J/g.

9. Cable according to the preceding Claim 8, characterized in that  
15 the enthalpy of fusion of the said thermoplastic polymer is greater than 85 J/g.

10. Cable according to any one of Claims 7 to 9, characterized in that the amount of thermoplastic polymer is from 10 to 50%, preferably from 20 to 40%, by weight relative to the total weight of the said mixture.

20

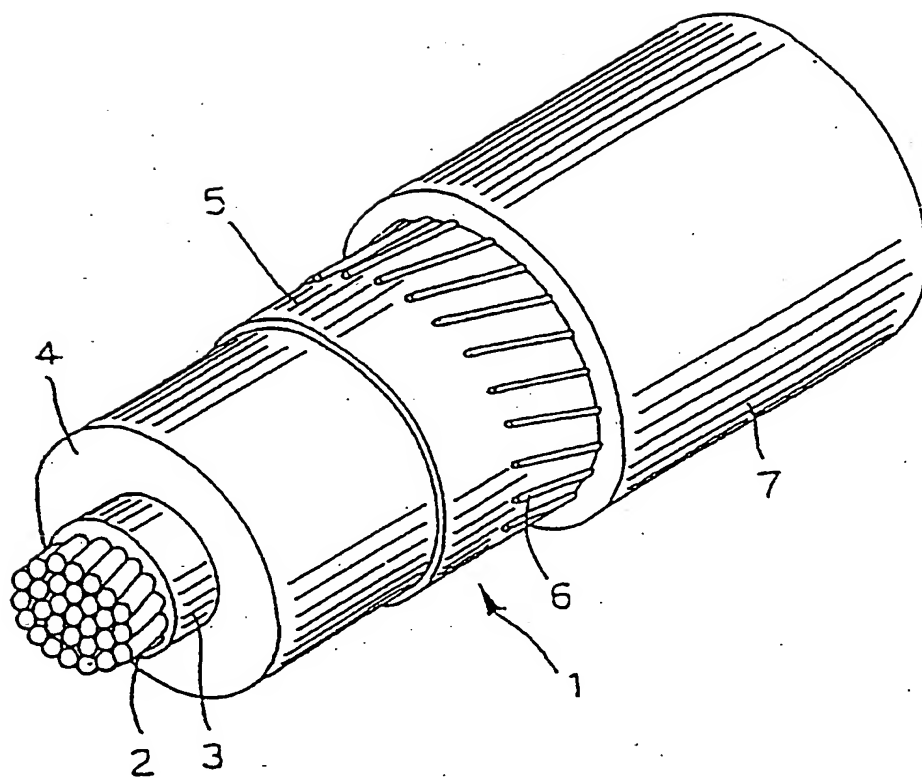


FIG. 1

2/5

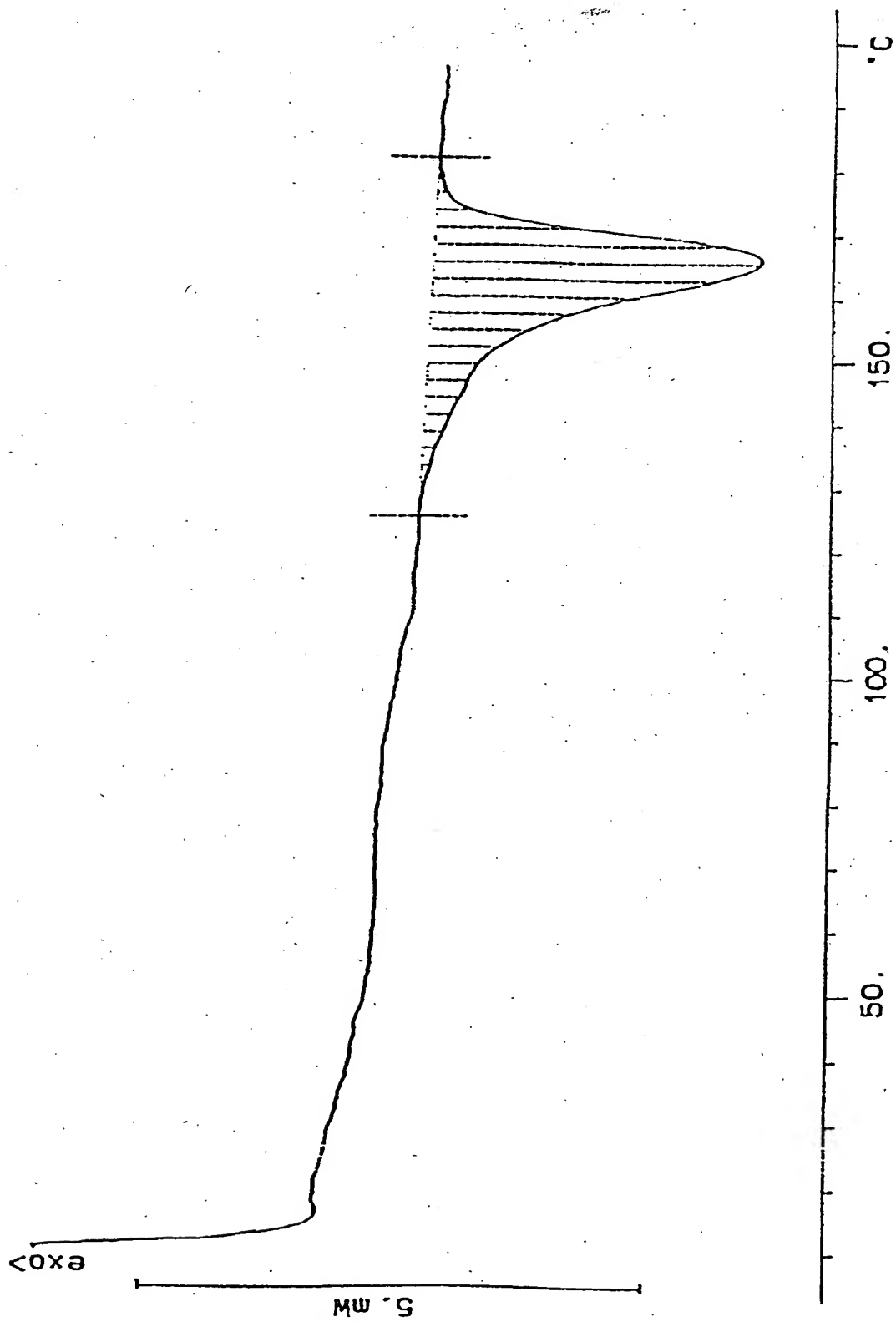


FIG. 2

3/5

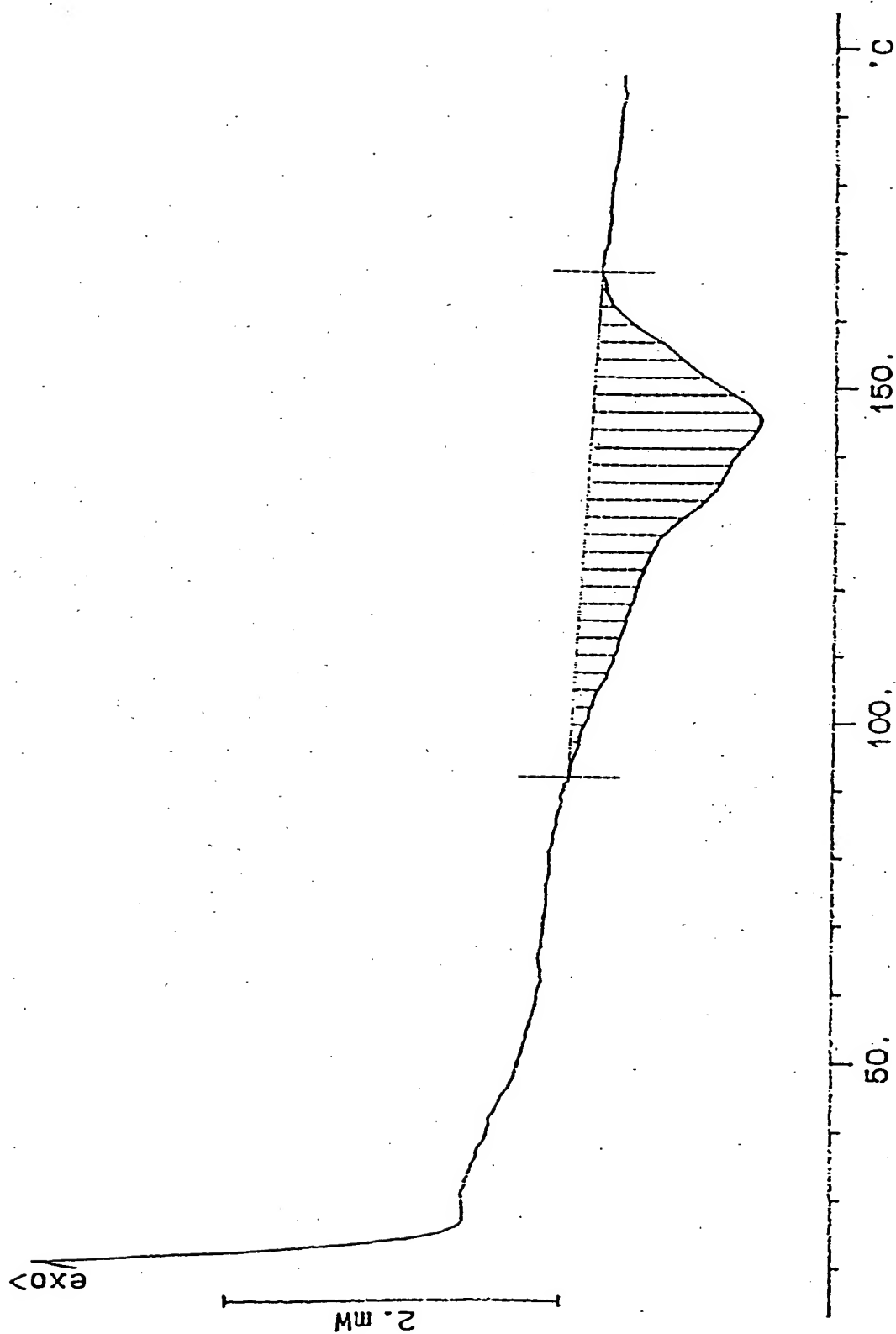


FIG. 3

4/5

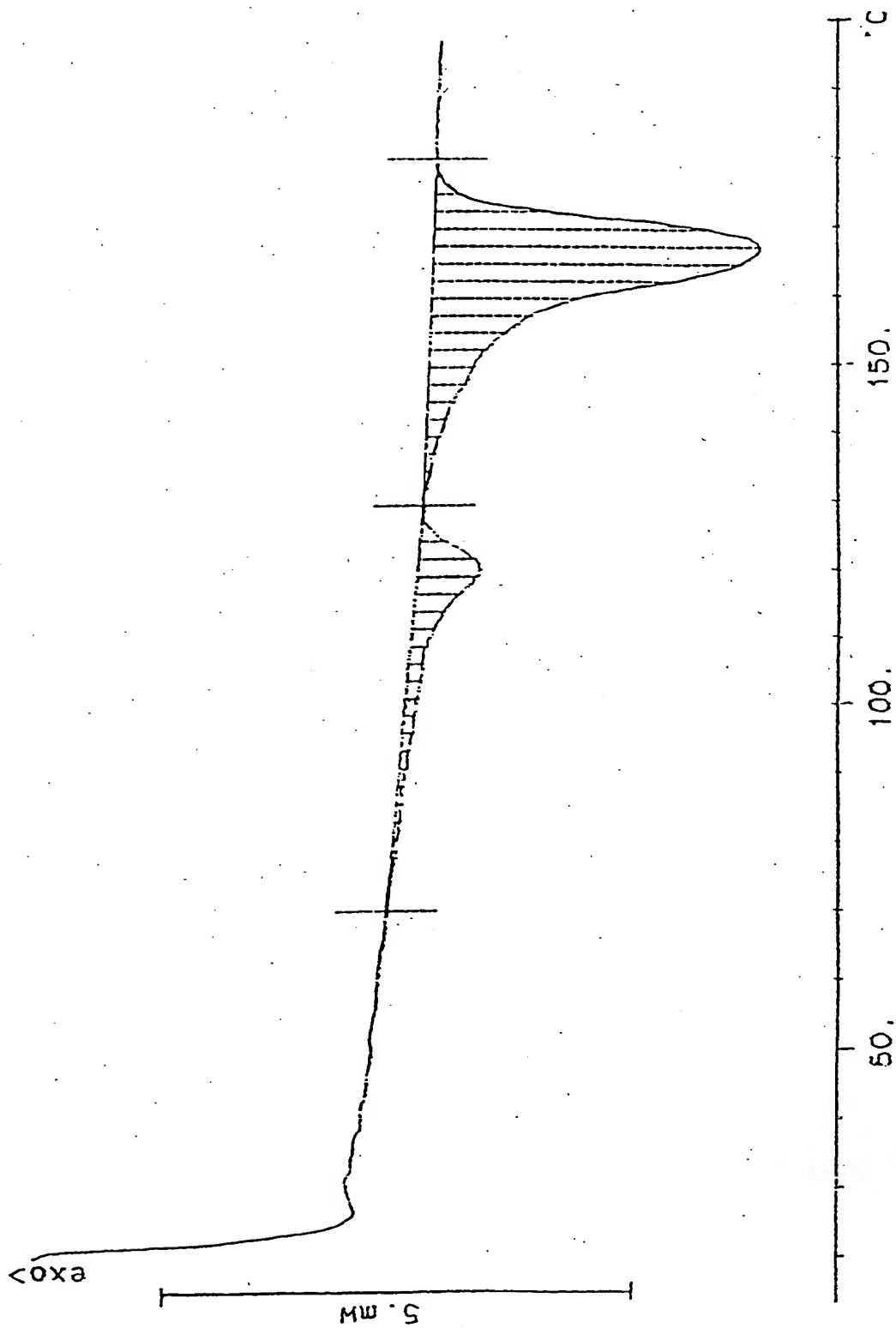


FIG. 4

5/5

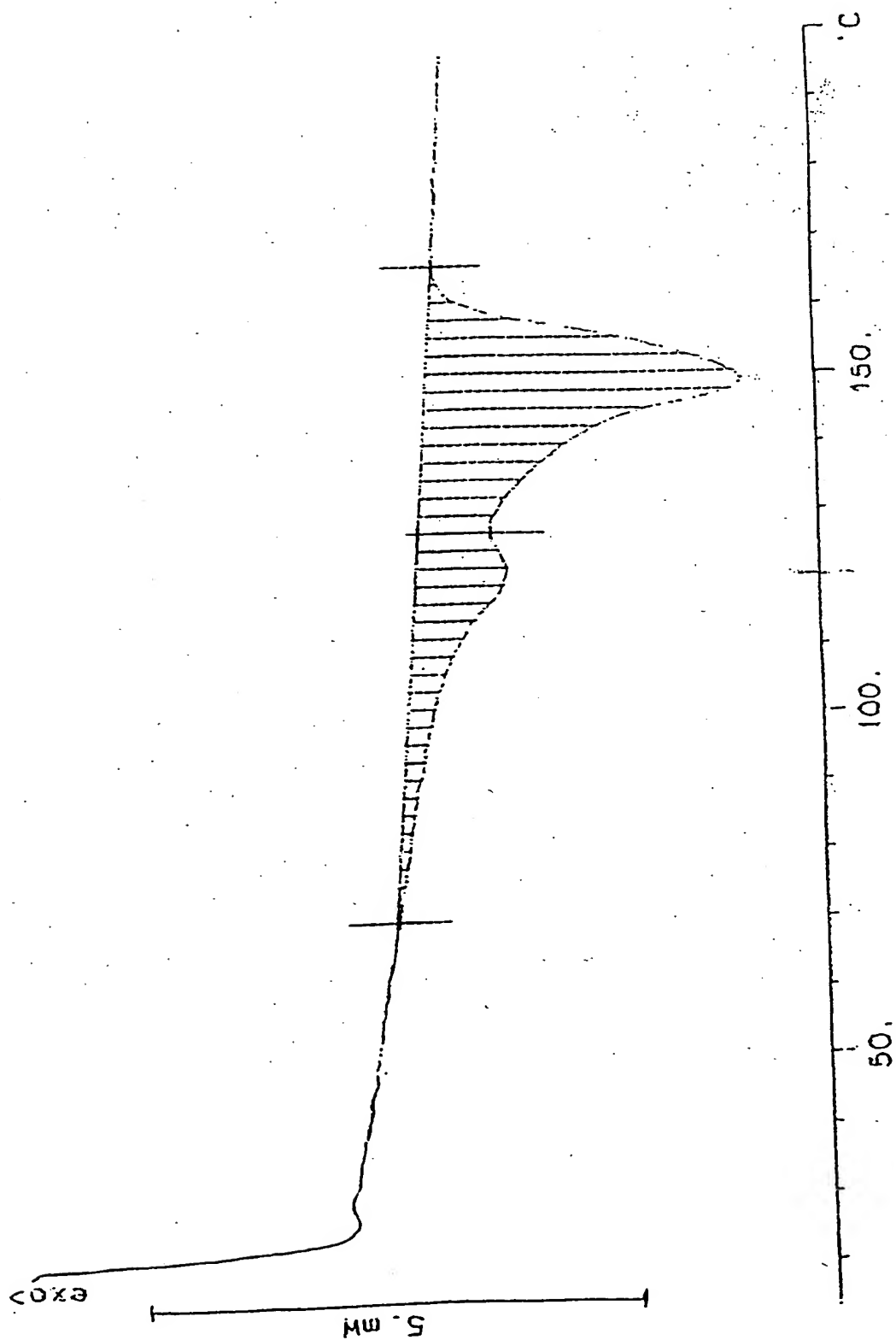


FIG. 5



# INTERNATIONAL SEARCH REPORT

Internal Application No  
**PCT/EP 99/10296**

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 H01B3/44 C08L23/16

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H01B C08L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 527 589 A (UBE INDUSTRIES ;UBE REXENE CORP (JP)) 17 February 1993 (1993-02-17) example 5 claims 4,7	1-10
X	EP 0 472 946 A (HIMONT INC) 4 March 1992 (1992-03-04) page 2, line 38 page 4, line 38; claim 1	1,2,5-10
X	EP 0 400 333 A (HIMONT INC) 5 December 1990 (1990-12-05) cited in the application page 2, line 8 page 2, line 51 - line 52 claim 1	1,2,5-10
	-/-	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

### \* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- "&" document member of the same patent family

Date of the actual completion of the international search

**27 April 2000**

Date of mailing of the international search report

**15/05/2000**

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3016

Authorized officer

**Paalman, R**

# INTERNATIONAL SEARCH REPORT

Internal Application No  
PCT/EP 99/10296

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, X	EP 0 893 801 A (PIRELLI CAVI E SISTEMI SPA) 27 January 1999 (1999-01-27) table 1	1,2,5-10
A	WO 96 23311 A (SIEMENS AG) 1 August 1996 (1996-08-01) cited in the application page 4, line 30 - line 35	1-10

# INTERNATIONAL SEARCH REPORT

information on patent family members

International Application No

PCT/EP 99/10296

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0527589 A	17-02-1993	AU 660184 B	15-06-1995
		AU 2092892 A	11-02-1993
		DE 69225749 D	09-07-1998
		DE 69225749 T	01-10-1998
		JP 5194802 A	03-08-1993
		US 5468807 A	21-11-1995
EP 0472946 A	04-03-1992	IT 1243188 B	24-05-1994
		AT 130320 T	15-12-1995
		AU 643810 B	25-11-1993
		AU 8140791 A	06-02-1992
		BR 9103295 A	26-05-1992
		CA 2048152 A	02-02-1992
		CN 1059537 A	18-03-1992
		CS 9102393 A	19-02-1992
		DE 69114613 D	21-12-1995
		DE 69114613 T	30-05-1996
		ES 2080863 T	16-02-1996
		FI 913681 A	02-02-1992
		HU 61784 A	01-03-1993
		IL 98936 A	31-01-1996
		JP 6025367 A	01-02-1994
		MX 9100433 A	01-04-1992
		NO 301023 B	01-09-1997
		PL 291297 A	01-06-1992
		PT 98541 A	30-06-1992
		SK 280009 B	12-07-1999
		RU 2036942 C	09-06-1995
		US 5286564 A	15-02-1994
		ZA 9105782 A	29-04-1992
EP 0400333 A	05-12-1990	IT 1230133 B	14-10-1991
		AT 130014 T	15-11-1995
		AU 634229 B	18-02-1993
		AU 5457090 A	01-11-1990
		BR 9001989 A	13-08-1991
		CA 2015683 A	28-10-1990
		CN 1047514 A	05-12-1990
		CZ 9002110 A	13-08-1997
		DD 294031 A	19-09-1991
		DE 69023392 D	14-12-1995
		DE 69023392 T	15-05-1996
		ES 2081870 T	16-03-1996
		FI 99016 B	13-06-1997
		HU 55814 A	28-06-1991
		IL 94153 A	21-10-1994
		JP 2950908 B	20-09-1999
		JP 3205439 A	06-09-1991
		KR 160511 B	15-01-1999
		MX 20476 A	01-12-1993
		NO 176442 B	27-12-1994
		PL 164127 B	30-06-1994
		PT 93922 A, B	20-11-1990
		RU 2092502 C	10-10-1997
		US 5302454 A	12-04-1994
		YU 82690 A	31-10-1991
		ZA 9002972 A	30-01-1991

# INTERNATIONAL SEARCH REPORT

information on patent family members

International Application No

PCT/EP 99/10296

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 0893801	A	27-01-1999	IT MI971741 A	25-01-1999
			AU 7730698 A	04-02-1999
			AU 8631398 A	16-02-1999
			BR 9802553 A	21-12-1999
			WO 9905688 A	04-02-1999
			JP 11111061 A	23-04-1999
			NZ 330986 A	28-05-1999
WO 9623311	A	01-08-1996	DE 19503672 A	01-08-1996
			AT 178736 T	15-04-1999
			DE 59601605 D	12-05-1999
			EP 0806048 A	12-11-1997
			ES 2132873 T	16-08-1999
			HU 9800337 A	29-06-1998
			NO 973316 A	25-09-1997